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AIR SUPERIORITY: IS THE F-35 AIRCRAFT WORTH THE COST?

by

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ABSTRACT

This research paper evaluates the United States air superiority capabilities along with emerging threats and other world capabilities. The research will be used to determine the value of the F-35 aircraft and its significance to the United States air superiority. The evaluation framework will be used to assess the health of the current fleet, enhancements provided to legacy aircraft, and emerging world military capabilities and threats. The F-35 program is over budget and behind schedule undergoing the heavy scrutiny of its existence. Despite the high price tag of the F-35, the findings will conclude if the F-35 should be pursued for production.

The evaluation exposed an aging fleet with vulnerabilities that are increasing consequentially intensifying maintenance and cost. Red Flag exercises demonstrated the F-35 intensifies the capabilities of Fourth Generation aircraft. The F-35 can find, detect, track, engage and destroy its target while sharing everything it sees with other aircraft and operation centers. Emerging threats from China and Russia have been aggressive leaving the United States facing security challenges. China and Russia are recapitalizing their aging fighter fleets by investing in their own Fifth Generation aircraft. This evaluation concluded that air superiority in the future would be reliant on technologically advanced aircraft making the production of the F-35 essential.

INTRODUCTION

Technological advancements integrated into modern warfare are rapidly changing the battlefield for the United States, its allies, and their enemies. No longer can the United States' capability of gaining air superiority be assumed and taken for granted. The national security of the United States and its allies' security continue to rely on the U.S. air superiority as necessary to conduct effective offensive and defensive combat operations. To maintain air superiority, the United States must change its expectations and assumptions through the use of advanced aircraft and operations.

In future conflicts, the United States cannot assume air superiority as a given, which has been the case in the Iraq and Afghanistan conflicts. Both China and Russia are perfecting their own Fifth Generation fighters.[1] Lieutenant General Schmidle defines the winner of aerial combat as, "The plane that shoots first wins, so it all comes down to detecting the enemy before he detects you."[2] To advance its fighter capabilities and maintain air superiority the Joint Strike Fighter (JSF) program needs an aircraft which can provide the speed, agility, and payload of legacy fighter aircraft combined with the advanced technological capabilities of stealth and Intelligence Surveillance and Reconnaissance (ISR).[3] This paper will provide capabilities analysis of the F-35 Lightning II also referred to as a Fifth Generation fighter, combining advanced stealth capabilities with fighter aircraft speed, agility, fully fused sensor information, and network-enabled operations.

Modern warfare technology applied to this airframe has come with an expensive price tag. The F-35 program is behind schedule and $163 billion over budget.[4] The aircraft is so expensive it dominates Congress's entire procurement budget.[5] There are numerous reasons why the program has exceeded the budgetary cost. The primary issue is that although a "one-size-fits-

all" warplane sounds good on paper and is an admirable goal, the problem of creating the perfect warplane is enormous. Packing every feature into one aircraft is going to be expensive. Further, continually adding features to the package during production causes the cost rise and become hard to control.

In addressing this concern, this paper explores the following question: Considering the cost and benefits of the F-35 aircraft, how valuable is the asset to the nation's defense, and should it continue to be pursued for production?"

The security of the United States' and its allies' continues to rely on the U.S. for air superiority. The F-35 can find, detect, track, engage and destroy its target while sharing everything it sees with other aircraft and operation centers.[6] The F-35 helmet mounted display increases pilot responsiveness and decreases pilot workload.[7] With growing competition from China and Russia perfecting their next generation aircraft, the United States must continue producing the advanced capabilities obtained in the F-35.

The national security of the United States requires battlespace dominance. The current fleet of aircraft can no longer meet all requirements because they are aging and require expensive service life extension programs. Further, current Fourth Generation aircraft are falling technologically behind, because many countries are now developing Fifth Generation replacements. Potential enemies are enhancing aircraft and equipping them with advanced technology overruling the assumption of air superiority in future conflicts; therefore, the United States national security requires technologically enhanced aircraft. New technology in the F-35 allows for air-to-air combat, air-to-ground strikes, electronic attack, intelligence, surveillance, and reconnaissance (ISR) missions all while being merely undetectable. With these technological

advances, the F-35 can dominate the entire battlespace in offensive and defensive attacks no matter what the enemy brings to the fight. Acknowledging the cost is high, this research paper will explore if air superiority is contingent upon the production of the F-35. If this is the case, the price tag would be nominal for the payback the United States would maintain in air superiority. It should then be considered mandatory and a bargain.

Provided is a brief overview of the F-35 program and the challenges it is facing using primary and secondary sources through the evaluation methodology. This research paper will evaluate the health of the current fleet and costs associated with the service life extension programs. Capabilities of the F-35 and legacy aircraft will be compared and evaluated against emerging global threats. This paper will also evaluate how the F-35 fills the technological gap in older aircraft, making them more lethal. Primary sources will include an interview with the current 570th F-35 Depot Maintenance Squadron Director to provide an assessment of production and operational elements. An evaluation of other countries future aircraft and timelines will be conducted to detect requirements for air superiority. The research conducted provides an overall evaluation of the F-35 aircraft and existing capabilities, reaching the conclusion that after examining the cost and benefits, if continued production of the F-35 is worthwhile.

BACKGROUND

Overview of the F-35 Program

In 2001, Lockheed Martin's next Generation aircraft model, F-35 Lightning II, was chosen to be the first Joint Strike Fighter which would be produced for the United States and several U.S. allies. Eight of the allies are cost-sharing partners in the program. Upon its contractual award, the F-35 became the Department of Defense's (DoD) largest procurement program. Initial plans called for acquiring a total of 2,465 JSFs which is 409 more aircraft than the current plan. Hundreds of additional F-35s are being purchased by several U.S. allies.[8] The intentions are for it to be the primary fighter warplane for the United States for decades to come.

The F-35 is the first international Fifth Generation Fighter Aircraft. It is designed to control the battlefield with multiple mission capabilities incorporating advanced integrated sensors built into every aircraft.[9] Missions which were traditionally performed by small numbers of specialized aircraft, such as intelligence, surveillance, reconnaissance, and electronic attack missions, can be executed by a squadron of F-35s delivering new capabilities to many allied forces.[10]

The aircraft is developed, produced, and supported by an international team of leading aerospace industry leaders. Primary contractor, Lockheed Martin continues the aircraft research, design, and production. Principal partner Northrop Grumman builds the center and aft fuselages and provides expertise in the Low-Observable (LO) stealth technology. Pratt & Whitney is contracted to build the world's most powerful fighter engine, the F135. BAE Systems also contributes to the production of the fuselages, and sustainment of short takeoff and vertical landing, advanced lean manufacturing, flight testing and air systems.[11]

The F-35 was envisioned to be an affordable Fifth Generation strike fighter to be procured in three versions for the Air Force, the Navy, and the Marine Corps, to avoid the higher costs of developing, purchasing, operating, and supporting three separate tactical aircraft designs to meet the similar but not identical operational needs.[12] Each version was perceived to eventually replace the A-10 and F-16 for the U.S. Air Force, the F/A-18 for the U.S. Navy, the F/A-18 and AV-8B Harrier for the U.S. Marine Corps, and a variety of fighters for twelve global participants.[13] The major differences between each version include the takeoff and landing, fuel capacity, and carrier suitability.

Issues and Challenges of the F-35 program

Technology is boosting airpower and enabling the U.S. to maintain air superiority more and more each day. However, technological enhancements do not come with a cheap price tag. The F-35, with an estimated $1.5 trillion price tag over the life of the program, has faced delays and is running over budget.[14]

The DoD Office of the Director, Operational Test and Evaluation compiles an annual report on the progress and failures of the F-35 program each year. Below is a summarization of the key problems they have identified over the past years driving schedule delays and price overruns.

Several software deficiencies have been identified causing setbacks and increased spending. One major setback is the aircraft's Block 2B software revealing deficiencies in fusion, electronic warfare, and weapons employment resulting in limited ability to respond to threats. Block 2B F-35 aircraft are limited to two air-to-air missiles; therefore, they require support from other aircraft if operations are contested by enemy fighter aircraft.[15] In 2015 Block 2B

development had so many deficiencies and limited combat capabilities that developmental flight testing was terminated and focus was transitioned to Block 3i and 3F development and testing.[16] Software packages dealing with sensors also continue to run into difficulties with the report revealing on-board and off-board sensors were deficient exhibiting high false-alarm rates and false target tracks and poor stability performance.[17] The need to continue to budget for software test points is a result of the immature capabilities in early versions of the software.

A 2013 analysis demonstrated vulnerabilities in the fuel tank structure to fuel ingestion and fuel and hydraulic fire requiring a complete re-design of the fuel tank. The analysis also triggered further test to reveal the redesign had problems with aircraft integration requiring yet further hardware and software modifications.[18]

Engine failure in June 2014 resulted in Aircraft Operation Limitations (AOL) on speed, g-load, maneuvers, and rudder input. In result of the restrictions, multiple deficiencies in mission systems, aircraft grounding, and subsequent flight restrictions were caused which put a delay on numerous test points that were already behind schedule.[19] Each delay has a domino effect throughout the program.

The Automatic Logistics Information System (ALIS) monitors all operations and maintenance for each aircraft providing pilots and maintainers with aircraft statistics and traceability of specific modifications. The system has several deficiencies. The major deficiency providing invalid data that portrays a condition of the aircraft and is currently behind schedule with upgrades delayed and deferred to later builds.[20] If ALIS is not fully functional, the F-35 could not be operated as frequently as intended. Retired Lieutenant Colonel now current 570th F-35 Depot Maintenance Squadron Director, Greg Hoffman, discussed how ALIS has brought a

new way of tracking maintenance but has also required an additional overhead cost of personnel at the depot to troubleshoot and maintain the system.[21] DoD has estimated total ALIS costs to be about $16.7 billion over the F-35's 56-year life cycle. DoD analysis found schedule slippage and functionality problems with ALIS could lead to $20-100 billion in additional costs.[22]

This annual report portrays how expensive new technology can be. It also offers proof of just how flawed new, never- tested -before technology can be in attempting to meet specification qualifications. Several unknown deficiencies have caused rework, schedule delays and restrictions resulting in overall program cost overruns.

EVALUATION OF CAPABILITES

Health of Current Fleet

The current U.S. military fleet of warplanes is older than any other time in our nation's history. Past conflicts and wars in Iraq and Afghanistan have caused airframes to wear out faster over their heavy usage.[23] The military is spending 87 percent more on maintenance than it did in the 1990s' due to aircraft flying more missions in harsh environments.[24] Additionally, the military has the oldest aircraft fleet in its history with an average age of 25 years.[25] Figure 1 is a compilation of data from the *2016 Index of United States Military Strength* for an average age of attack aircraft.[26] Data reveals the fleet is aging and leaves the United States with a potential vulnerability requiring legacy programs to undergo a Service Life Extension Program (SLEP).

Service	Inventory	Average Age	Service	Inventory	Average Age	Service	Inventory	Average Age
Airforce			Marine			Navy		
A-10	359	32	EA-6B	29	26	F/A 18 A-D	455	23.5
F-16	913	23.9	AV-8B	142	17	F/A 18 E/F	563	12.4
F-15	438	26.7	F/A 18 A-D	237	22.5			
F-22	177	6.9						

Figure 1: Average Age of Attack Aircraft

Each year aircrafts are brought to the depot for scheduled modification to enhance their capabilities. Various programs are planned to modify sections of the aircraft for each weapon system. Each program has a set of planned operations for mechanics to perform to complete each program. While performing those operations, if a mechanic identifies a safety of flight issue Over and Above (O&A) operations are added to the work package which extends the days the aircraft is at the depot for modification resulting in an increase of cost for material and manpower not planned for the program.

Data in Figure 2 generated from the maintenance operating system at Hill, AFB, is a compilation of the number of O&A operations and location for Fiscal Year (FY) 16 and FY17 Q1. The depot is facing O&A operations ranging from multiple cracks, excessive fuel leaks, corrosion, worn, deteriorated, torn or even missing parts as well as broken wiring causing the

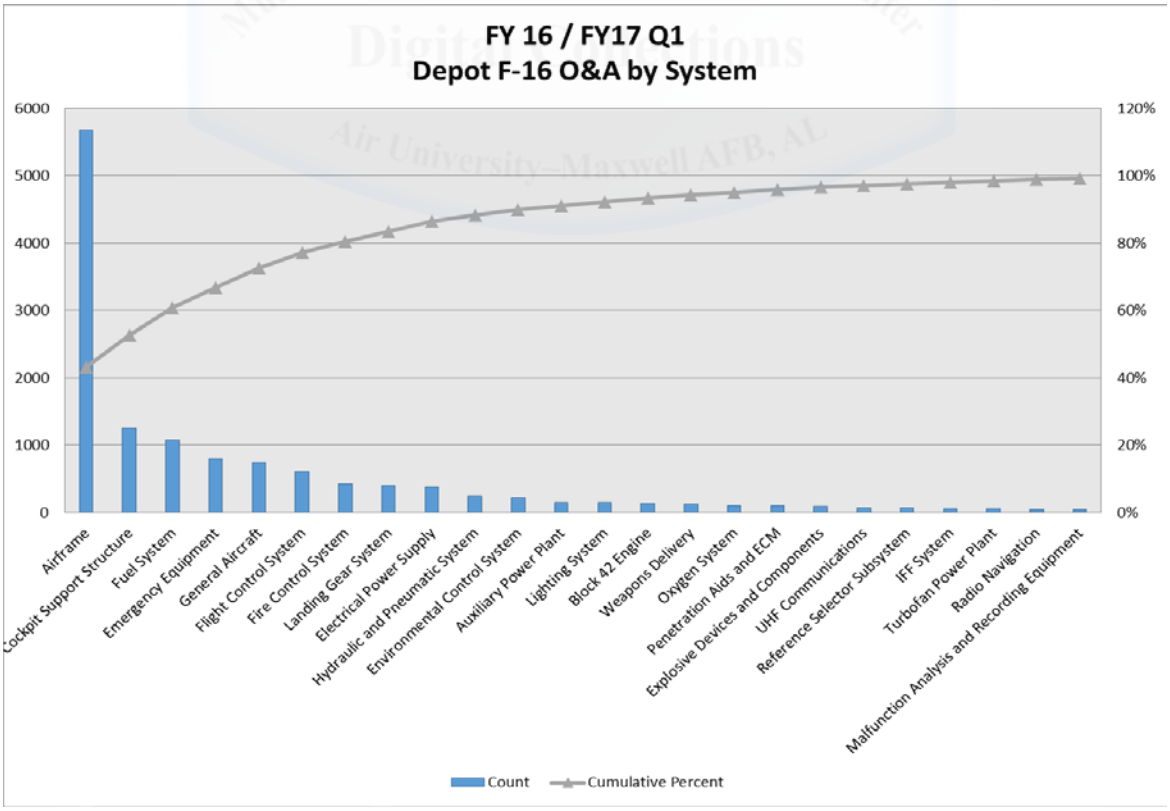

Figure 2: Operation and Location of O&A Operations

complete rewiring of the aircraft. A root cause analysis was conducted determining the only common factors for the defects the aircraft is experiencing are age and heavy usage.

Since 9/11, the F-16 has been flying thousands of sorties as part of a major component of the combat forces committed to the war on terrorism.[27] The combination of old age and increased flying hours caused the F-16 to undergo a high volume of O&A operations being performed to the aircraft. The average age of aircraft inducted into the depot for the sample size was 28 years. There was a total of 13,152 operations which resulted in 43,000 hours costing the program an additional $9.4M.[28] 479 of those operations were completed on aircraft inducted at the depot for a simple Speed Line Paint modification. The figures 3 through 5 display O&A issues experienced on the speed line paint program requiring extensive structural repair. These O&A operations have extended the time aircraft are at the depot from 35 planned days to an

Figure 3: F-16 Corrosion on Speed Line Paint Modification

average of 101 days, delaying the scheduled completion and resulting in a reduction of 16 planned aircraft inducting into the depot for modifications.[29]

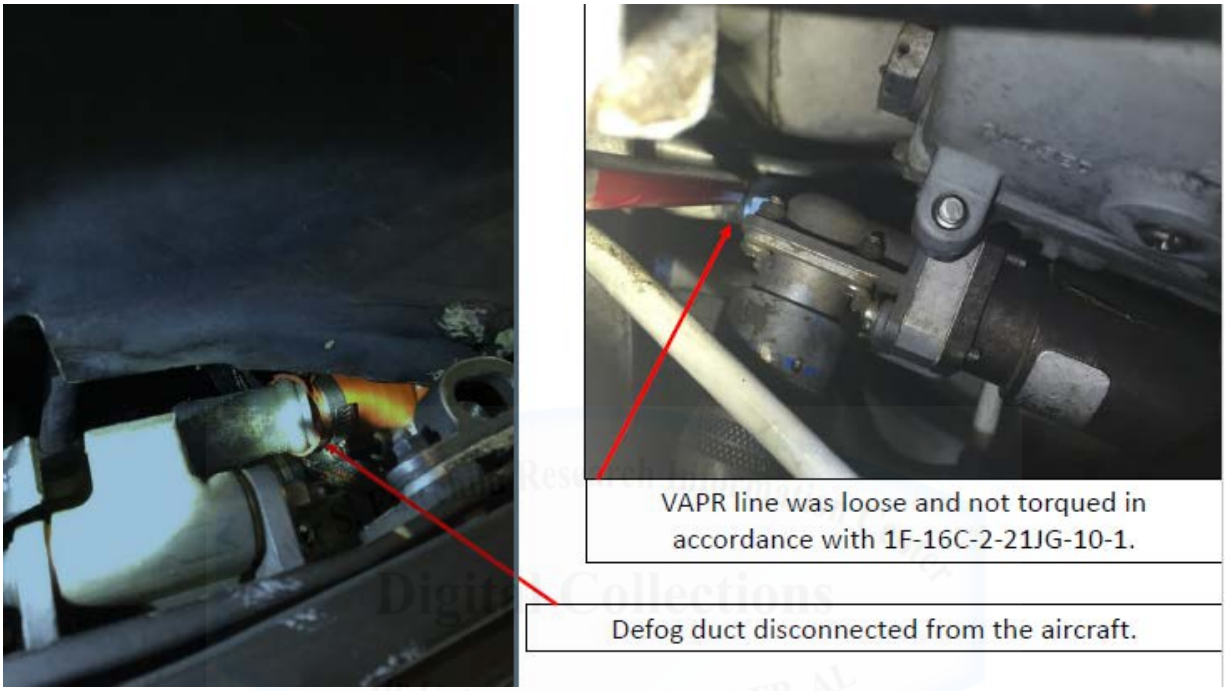

Figure 4: Safety of Flight Concerns on F-16

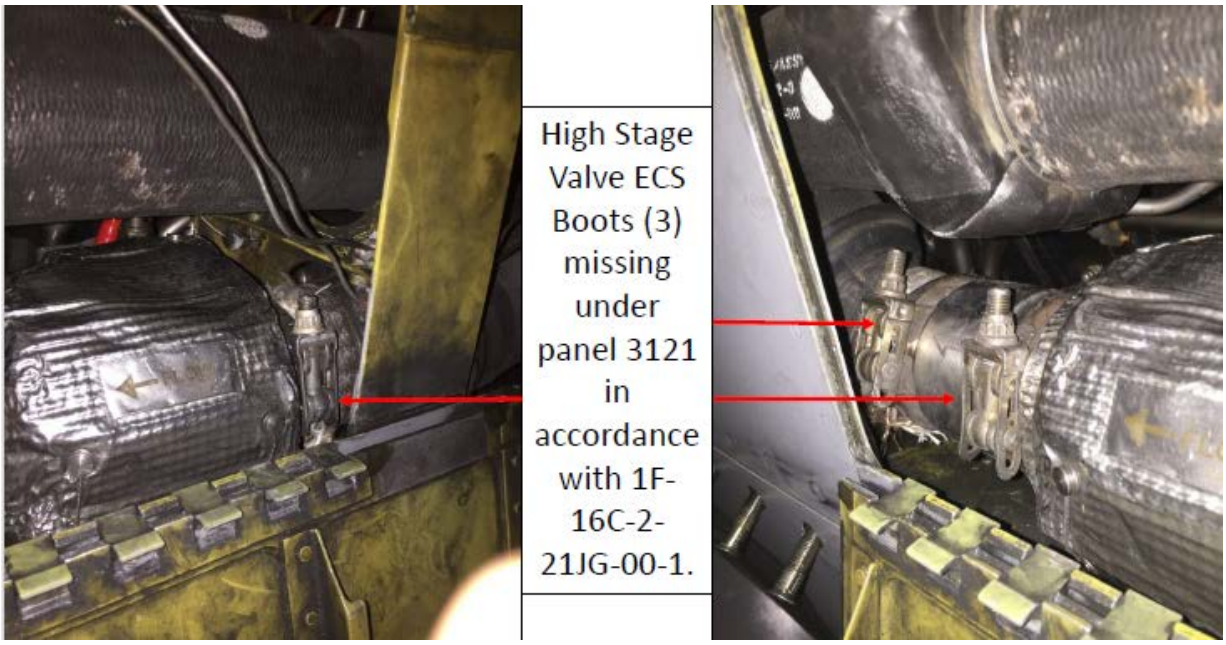

Figure 5: Missing High State Valve on F-16

Aircraft have also had cracks identified in the wings requiring unexpected O&A wing replacements at $1M per aircraft with a total net fleet cost of $7M[30] for the duration of the above analysis. A secondary effect of this is leaving those aircraft out in the field in their current state with the same flaws as those at the depot giving rise to safety and effectivity of those aircraft.

F-16 average service life experiencing those vulnerabilities is 23.14 years at 8,000 hours of flight.[31] The Air Force is extending the service life by commencing a SLEP for up to 350 F-16s at $2.8 billion to keep the fleet as combat-ready as possible and extending the life to 10,000 to 12,000 hours.[32] SLEP will extend the life of the F-16 to eliminate structural vulnerabilities of the old fleet while the F-35 is brought onboard to operate. With SLEP being a structural upgrade to the F-16, it will not enhance the aircraft to acquire the capabilities of the F-35, but merely extends its service life similar to what has been done on the A-10.

There has been controversy over the last several years about retiring the A-10 aircraft in an effort to offset the cost of the F-35A.[33] The Air Forces primary justification for retiring the A-10 is the cost savings of $4.2 billion a year.[34] However, the Air Force budget argument fails to address total defense expenditures and operational requirements.[35] The A-10's ability to fly low and slow combined with its strafing capacity make the A-10 ideal for Close Air Support (CAS).[36] These limited capabilities make it clear the A-10 is not the multipurpose aircraft the F-35 is designed to be.

Figure 1 reflects the average age of the Air Force A-10 to be 32 years requiring the aircraft to either be retired or undergo a SLEP. Despite the argument of the $4.2 billion a year savings, 90 percent of A-10 aircraft[37] underwent a SLEP program to extend the aircraft life from 8,000 to 16,000 hours keeping them in service until CY2028. See figure 6.[38]

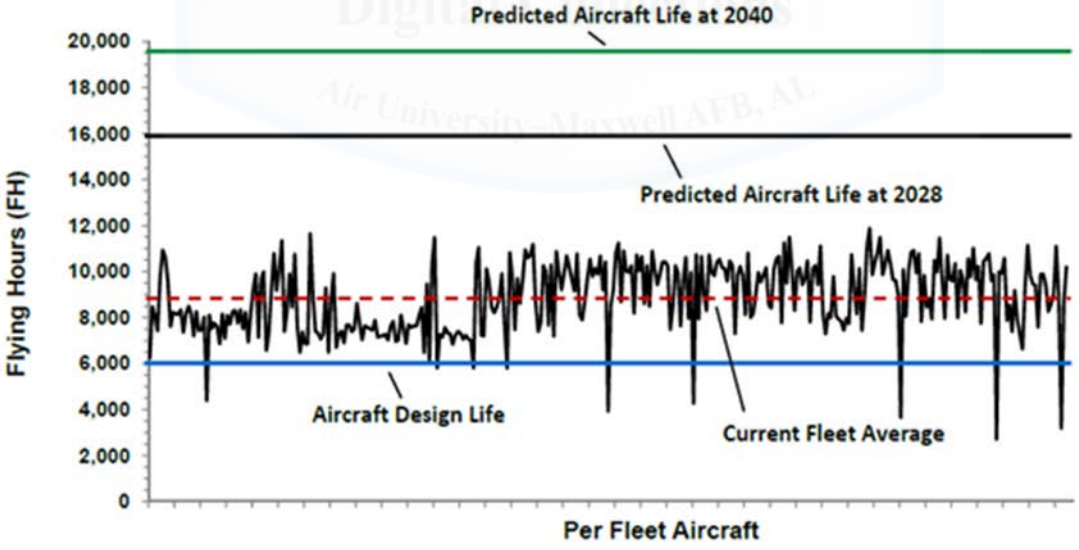

Figure 6: Service Life of A-10

The A-10 SLEP addressed flying hour limited critical structural areas prone to fatigue. A-10 wing assemblies approached service life limits for critical structural components within the

Wing Center Panel (WCP) and Wing Outer Panels (WOP).[39] This program updated those wings to current year configuration and structural repairs while removing the wings and overhauling the aircraft fuselage. The A-10 SLEP was estimated to cost $2,894,008 per aircraft with an estimated 5,185 hours totaling $934,764,503.[40]

With both of these aging platforms undergoing a SLEP, the United States and its allies are counting on these aircraft to back Iraqi forces to advance in the fight against Islamic State of Iraq and Syria (ISIS). In the fight against ISIS, the Air Force has flown more than half of the

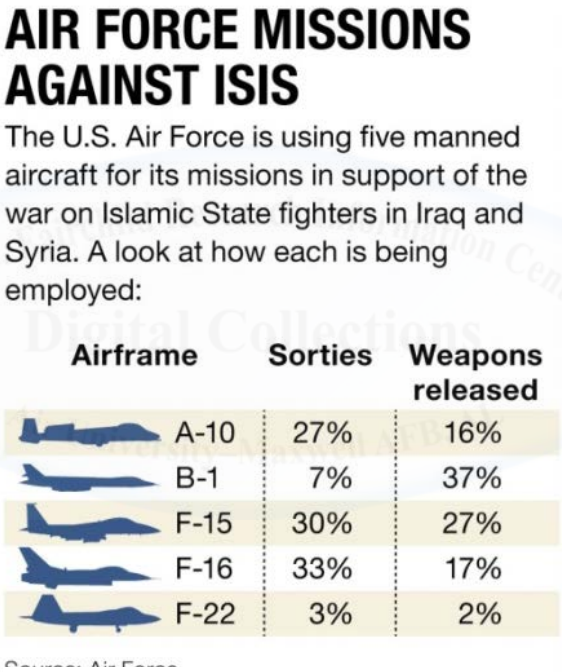

Figure 4

87,000 coalition sorties and (Figure 7 illustrates the F-16 and A-10 being heavily used for the air strikes. In an interview with retired Lieutenant Colonel now current 570th F-35 Depot Maintenance Squadron Director, Greg Hoffman, revealed that the A-10 may take a long time to get to battle, but despite that, on his aircraft experience in Iraq and Afghanistan the preferred fighter for CAS was the A-10.[42]

Figure 7: Air Force Missions Against ISIS

Unfortunately, the presence that the U.S. military has in the fight against ISIS will take a toll on the current fleet of aircraft which is already old and have either undergone or going through a SLEP program. Wear and tear on the older fleet will start to cause vulnerabilities on the aircraft which are deployed and providing the U.S. with its air superiority. With the extensive amount of use and flying hours, the O&A operations will only increase as they are brought in for other modifications, driving an increased cost to maintain the legacy platforms.

The United States and its allies are relying on an older fleet that is shrinking over time. The fleet has gone or is undergoing SLEP to try to eliminate vulnerabilities on the aircraft providing the air support that is required for the United States national security interest.

The next section of this research paper will address how the F-35 can make these legacy aircraft more lethal and counterbalance their flying hours during air support. The F-35 has the capability to offset the pace of the wear and tear that is occurring on these aircraft and will reduce O&A operations occurring during modification.

Assisting Other Aircraft to be More Lethal

Deployment of the F-35 will incorporate working with legacy aircraft to force multiply their capabilities.[43] The F-35 has the ability to support legacy aircraft to achieve mission success and survivability using a combination of stealth, electronic attack, and information sharing.[44] Being the first fighter equipped with satellite communications capable of integrating beyond the line-of-sight communication's the F-35 has the ability to process data and translate messages in the air to legacy aircraft and surface teams in real time.[45] The F-35 provides the military fleet with the ability to share information as a team versus having systems which do not communicate

or are not designed from inception to communicate with each other. These features will allow for effective collaborative decision-making across all platforms.

The integrated and fused sensor called the Multifunction Advanced Data Link (MADL) on the F-35 allows pilots to see a single integrated picture of the battlespace. The MADL also automatically shares data with other pilots on the network using the most modern data links. This feature allows the F-35 to automatically share situational awareness data while assuring a secure transmission. Sharing its operational picture with other platforms, the F-35 will be suited for coalition operations by providing allied fleets with operational information to ultimately dominate the tactical environment.[46]

Red Flag exercises at Nellis Air Force Base in Nevada are one of the most realistic and challenging aviation warfare exercises which exist for pilots. The 2017 Red Flag exercise included surface-to-air missiles (SAMs), radar jamming equipment, and an increased number of mock enemy aircraft.[47] Pilots from the 2017 event say the Air Force's F-35A exceeded expectations by dominating the air space and improved lethality of other legacy aircraft, scoring an impressive 15:1 kill ratio.[48] The F-35 advanced avionics software stole the show as it successfully compiled data into a detailed layout of the battlefield with each specific threat pinpointed.[49] Even when the F-35 ran out of munitions, pilots demanded the F-35 remain in the combat zone to absorb data and relay the target information to the older fighters.[50] After the F-35 had wiped out ground threats, the multirole aircraft was able to defend the air arena with air-to-air missiles, taking out aircraft that did not even know it was there.[51]

Lieutenant Colonel George Watkins, 34th Fighter Squadron Commander, described the battle space as seeing multiple advanced threats at one time where in the past it was one

advanced threat and everything from F-16s, F-15s, F-18s, and missiles would have to attack it to take it out.[52] He stated, "When you pair the F-22 and the F-35 together with the Fourth Generation strikers behind us, we are able to dominate the air space over the Nellis test and training range."[53]

The F-35 enhances today's older fleet to work more effectively by acting as a communications gateway for numerous other platforms, enabling strike and anti-air attacks with stand-off weapons.[54] Air operations and air-surface integration will be transformed with real-time communication, providing an opportunity to make decisions across all platforms during battle. Capabilities will also expand by collaboratively sharing information with allies to effectively achieve mission success and survivability.[55] The battlespace awareness, sensor fusion, electronic attack, and protective capabilities all allow the F-35 to assist legacy aircraft to be more lethal and dominate the battlefield, providing capabilities to ensure the United States and its allies maintain the national security they desire. Enhancing the lethality of legacy aircraft is vital, and the capabilities that allow the F-35 to achieve this are exclusive to the program declaring its existence to be imperative. While this section covered how the F-35 reduces the gap between legacy aircraft, the next section will cover what sets the F-35 apart from legacy aircraft.

F-35 Capabilities Compared to Legacy Platforms

Fifth Generation technology was designed to penetrate denied airspace. Specifically, the F-35 is advertised as a multirole follow-on to the current fighter aircraft. The F-35 shown in figure 8 is not a chronological replacement to any airframe, but a Fifth Generation platform which demands increased information.[56] One cannot think of the subject of intelligence support for the Fifth Generation aircraft with a Fourth Generation mindset.[57] The F-35 was designed to survive in an anti-access threat environment, using numerous advanced capabilities, representing a quantum leap in air dominance.[58]

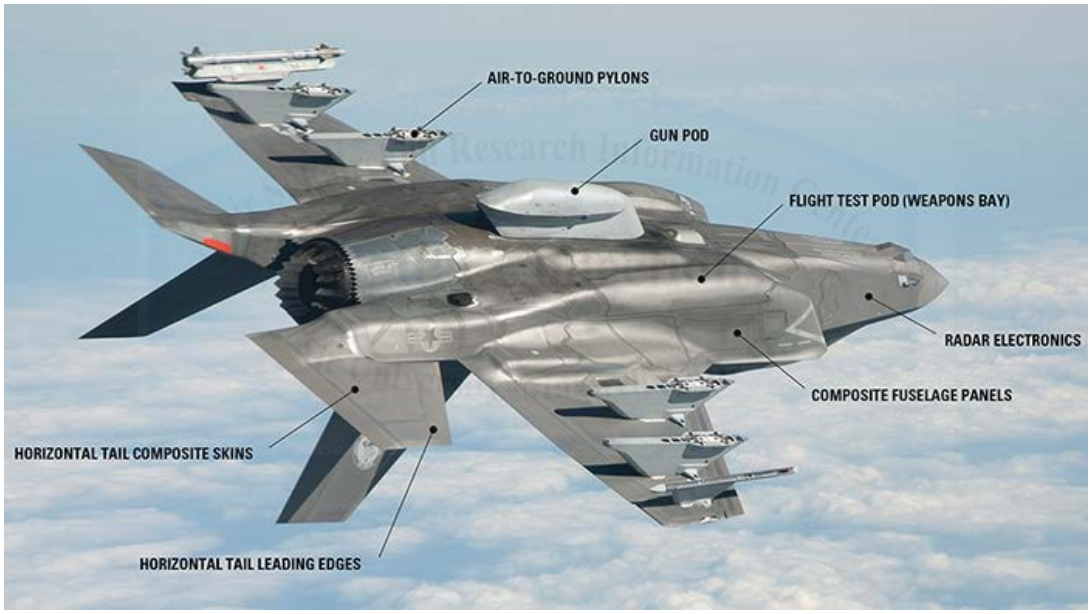

Figure 8: F-35B On Board USS America

The need to be faster, fly higher or farther than legacy aircraft were not the necessities which drove the production of the F-35.[59] The big appeal is that the F-35 packs a lot of specialized reconnaissance, electronic warfare, and jamming gear that in current warfare require a specialized aircraft called enablers to be brought in to fight.[60] Normally, aircraft are specialized for specific warfare capabilities. The F-35's advanced stealth and built-in electronic warfare

capabilities allow for extraordinary battlefield access without the need for dedicated electronic attack aircraft support while maintaining air to air combat capability.[61]

With advanced electronic warfare capabilities, the F-35 can locate and track enemy forces, jam radio frequencies and disrupt enemy attacks with unmatched precision.[62] Each variation of the F-35 is equipped with an Active Electronically Scanned Array (AESA) that includes false targets, network attack, advanced jamming and algorithm-packed data streams.[63] AESA allows the F-35 to employ precision-guided bombs such as Joint Direct Attack Munition (JDAM), Joint Standoff Weapon, AIM-120C radar-guided Advanced Medium-Range Air-to-Air Missile (AMRAAM), and AIM-9 infrared-guided short-range air-to-air missile.[64] AESA provides the F-35 the capability to destroy long -range targets. In 2017, for the first time, Red Flag exercise put to test the precision targeting capability without the common use of Tomahawk missiles as in the past. Lieutenant Colonel George Watkins stated, "We would shoot everything we had at that one threat just to take it out. Now between us and the (F-22) Raptor, we are able to geo-locate them, and precision target them. With the stealth capability of the F-35A, we can get close enough to put a bomb right on them. That would be impossible with a Fourth Generation aircraft."[65]

In addition to precision targeting AESA provides the F-35 with fully integrated radar warning and self-protection to detect and defeat surface and airborne threats. When it comes to fighter jets, who sees who coming first is essential to conquering the battle. Aircraft can be made stealthy with Low Observable (LO) coating to make them hard for other aircraft to see while utilizing radar and other sensors.[66] When the enemy utilizes advanced design, tactics, and technology; the stealth exterior of the F-35 complicates the enemy's ability to see or find it.[67]

Extensive analysis has been conducted on the survivability of the F-35 with the combination of its stealth, advanced sensors, and electronic attack.[68]

Stealth allows the F-35 to penetrate denied airspace that legacy fighters cannot penetrate by evading detection by radar, infrared sensors, and emission interception.[69] U.S. Air Force leadership considers advanced stealth technology "the price of admission" into modern warfare. Stealth may not be new but combined with multirole capabilities the F-35 is already proving to be a game changer in its initial test phase.[70] Maj James Schmidt, a former A-10 pilot, described his red flag experience where the four-ship formation destroyed five surface-to-air threats in a 15- minute period without being targeted once. He stated, "It was pretty cool to come back from a mission where we flew right over threats knowing they could never see us."[71] General Mark Welsh, Former Chief of Staff, U.S. Air Force stated, "In the near term, the stealth technology on our Fifth Generation platforms, the F-22 and F-35, is the price of admission into the fight. The lethal envelope of advanced air-defense systems continues to grow against our Fourth Generation aircraft."[72]

Adding to the stealth exterior is the F-35 robust communications suite of more advanced than any fighter aircraft built to date.[73] Advanced sensor fusion enables the pilot to draw information from on-board sensors generating images of the battlefield.[74] The exterior is equipped with a 360-degree spherical situational awareness system called the Distributed Aperture System (DAS), shown in Figure 9. Pictures gathered from the sensor fusion can be automatically shared with other pilots and command and control operating centers.[75] DAS is integrated with the advanced technology within the F-35 providing detection and tracking,

launch point detection, situational awareness, weapons support, day/night navigation, fire control capability, and precision tracking of surrounding aircraft for tactical maneuvering.[76]

The external and internal technological capabilities and design of the F-35 provide the aircraft with required features to excel in advanced threat environments. The F-35 has taken the advanced technologies one step further by not only assuring the pilot and base locations every necessary feature to be available to them but it provides the pilot with those features to be triggered or sent to the Helmet Mounted Display System shown in figure 10.

Figure 5: 360-Degree Distributed Aperture System

All the information that the pilot requires to complete his or her mission such as; airspeed, heading, altitude, targeting, information, and warnings are projected on the helmet's visor versus the legacy Heads-Up Display (HUD).[77] The advanced technology that sets the helmet apart from the HUD is provided through the DAS which delivers high-resolution real-time imagery to the pilot's helmet from six infrared cameras mounted around the aircraft allowing pilots to view all parameters outside the airplane.[78] It allows the pilot to view allies and threats above the horizon in the air. The camera also provides all ground concerns which may be of interest to them to provide immediate situational awareness.[79] The Helmet Mounted Display provides the pilot with the capability to conduct missions at night utilizing the night vision

through the integrated camera.[80] This advanced technology reduces the pilot's workload and increases responsiveness.[81]

A Lockheed Martin capabilities study captured results against legacy aircraft proving the F-35 is six times more effective in air-to-air missions, providing maneuverability, aerodynamics, range, and acceleration. It is eight times more effective in air to ground missions due to its stealth, sensors, and Helmet Mounted Display. Lastly, the F-35 was proven to be six times more effective in surveillance missions with its ISR capabilities penetrating farther into enemy

Figure 6: Helmet Mounted Display

integrated air defense systems.[82]

With an aging fleet which is not comparable to its predecessor the technology packed into the F-35 is securing air superiority to protect the national security interest of the United States and its allies'. The United States has designed and produced the F-35 to keep up with modern warfare technology. What technology has potential adversary's been developing? The next section will explore the United States adversary's potential future capabilities.

World Military Capabilities and Emerging Threats

The United States ability to control the air is often taken for granted. While budget pressures delay key investments, and scrutinize current developments, others continue to develop advanced technologies which will put pressure on air superiority.[83]

Despite the long track record, the United States is on track to lose air supremacy in contingencies involving near-peer air combat.[84] During red flag exercises Lieutenant Colonel George Watkins stated, "Just as we are getting new systems and technology, the adversary's threats are becoming more sophisticated and capable."[85] Legacy aircraft cannot succeed when they are up against advanced anti-air systems with sophisticated radar and infrared capabilities.[86] Since the Cold War, the United States and its allies have relied on the U.S. military to deter aggression and respond to a crisis.

Currently, China and Russia are violating international law and threatening United States allies.[87] Chinese and Russian warplanes have been aggressive in intercepting the U.S. military aircraft patrolling near the U.S. west coast. The U.S. also has concerns about Russia expanding its influence in Eastern Europe while China is invading the South China Sea.[88] China is attempting to establish control of the international airspace over the South China Sea.[89] The United States will face a more stressful set of security challenges with these concerns as China and Russia have also been developing their own Fifth Generation technological advanced aircraft.[90]

Russia has delivered its first multi-role Fifth Generation stealth aircraft the Sukhoi PAK FA T-50 displayed in figure 11 to compete with the United States Fifth Generation aircraft. Like the F-35 program, the T-50 has also been plagued by delays, cost overrun, and unsteady technology.[91] It is packed with the latest aviation technology, radar-absorbing materials and weaponry to provide excellent performance, agility, and response during conflicts.[92] Similar to the F-35 the PAK FA T-50 is jointly owned between Russia and India.[93] The F-22 is claimed to be the most agile aircraft the United States has built due to its 2D thrust-vectoring nozzles at the engines. The T-50 has 3D thrust-vectoring nozzles and will be even agiler than the F-22.[94] Russian Air Force and Indian Air Force have each ordered 200 T-50. The T-50 is in mass production with 55 aircraft to be completed by 2020. Russia is claiming it to be capable of outperforming the F-22 and F-35.[95]

Figure 7: PAK FA T-50

Russia's Sputnik news reports the T-50 is designed with an advanced defense system that can neutralize an enemy plane's stealth capability.[96] Composite materials allow the aircraft to be stealth along with low radar visibility and low heat signature and are enhanced with similar advanced electronic systems like the F-35.[97] With similar engines to the United States Fifth Generation aircraft it is designed to perform supersonic flights over 2,000 km/h and will perform short take-off and landing capabilities.[98] Similar to the F-35 the T-50 is equipped with advanced

communication technology which determines position and motion of parameters when in situations without satellite navigation and Russia's satellite-based navigation system.[99]

China is challenging the superiority of United States air power by developing its own Fifth Generation fighter called the Shenyang Gyrfalcon J-31, displayed in figure 12 is a multi-role, twin-engine stealth fighter that has the potential to become more than a match for the United States F-35.[100] The J-31 is intended to provide China with the advanced defense capabilities in close-air support, aerial bombing and air interdiction operations similar to the F-35.[101]

Figure 128: China Shenyang Gyrfalcon J-31 Fifth Generation Aircraft

Similar to the F-35, the fighter aircraft features Diverterless Supersonic Inlet (DSI) which at supersonic speeds provides a forward-swept inlet cowl, to redirect unwanted boundary layer airflow away from the inlet, basically performing the job of heavier, more complex, and more costly diverters used by current fighters.[102] The airframe is designed to incorporate low-aspect ratio trapezoidal planform wings with titanium spars.[103] It can hold one cannon and is equipped with two internal weapons bays and three payload hard-points.[104] The two engines on the J-31 are Russian developed engines and are designed to have a flatter fuselage than the F-35.[105] The flatter fuselage generates improved fuel efficiency and speed with an afterburning thrust of

84kN.[106] It reaches speeds of 2,200km/h and will offer a maximum range with assisted fuel tanks.[107] These capabilities make it clear that it is similar to dominating the air as the F-35 proved in the Red Flag exercises.

The J-31 is not the only Fifth Generation fighter aircraft for China. The Chengdu J-20 shown in figure 13 is proven to fly in disputed air and entered military service in March 2017.[108] With a reported top speed of 1,300 miles per hour and the ability to carry short- and long-range air-to-air missiles, the jet is often compared to the twin-engine F-22 Raptor.[109] Once the J-31 enters service, it is likely to serve alongside numerous J-20s as part of a "high/low" combination, similar to the F-35/F-22 mix in the US Air Force. It will also serve with various aircraft carriers enhancing the Chinese capabilities.[110] Not only will the J-31 enhance the defensive capabilities of China but it has also been sought out by Pakistan for purchase once reaching Fully Operational Capabilities (FOC).[111] This combination of Fifth Generation aircraft will provide China with a Fifth Generation combination similar to the advanced combo of the F-22 and F-35. The fact that China has invested in producing these Fifth Generation aircraft proves the risk of future air superiority for the United States.

Figure 9: China Chengdu J-2- Fifth Generation Aircraft

CONCLUSION AND RECOMMENDATIONS

In 2001, Lockheed Martin's next Generation aircraft model, F-35 Lightning II, was chosen to be the first Joint Strike Fighter produced for the United States and several U.S. allies. Upon its contractual award, it became the DoD's largest procurement program. Several unknown deficiencies have caused rework, schedule delays and restrictions resulting in overall program cost overruns. The F-35, which comes with an estimated $1.5 trillion price tag over the life of the program, has faced delays and is running over budget.[112] The intention for the F-35 is to become the primary fighter warplane for the United States for decades to come.

The United States and its allies' are relying on an older fleet that is shrinking overtime. Analysis exposed an aged fleet with the United States putting heavy flying hours on legacy aircraft in current conflicts causing a surplus of maintenance leaving aircraft with vulnerabilities in the battlefield. The extensive amount of use and flying hours will increase vulnerabilities over time on the aircraft jeopardizing the U.S. air superiority.

Technological advancements were highlighted as they are being integrated into modern warfare across the world proving the battlefield for the United States, its allies, and their enemy has changed. The technological advantage the United States has is decreasing with both China and Russia perfecting their own Fifth Generation fighters leaving the United States to not assume air superiority as a given. New technology in the F-35 allows for air-to-air combat, air-to-ground strikes, electronic attack, intelligence, surveillance, and reconnaissance (ISR) missions all while being merely undetectable. Red Flag exercises proved with these technological advances the F-35 enhances the capabilities of legacy aircraft sanctioning battlefield dominance.

While budget pressures delay key investments, and scrutinize current developments, others continue to develop advanced technologies which will put pressure on air superiority.[113] Legacy aircraft cannot succeed when they are up against aircraft with advanced, sophisticated capabilities.[114] The United States and its allies' rely on the U.S. military to deter aggression and respond to a crisis. Currently, the United States and its allies are experiencing aggression from China and Russia. The United States will face a more stressful set of security challenges as China and Russia have also been developing their own Fifth Generation technological advanced aircraft.

After compiling and reviewing the above said scientific research and interviews with active personnel involved in the F-35 Lighting II program, it is evident in the future air dominance will require an aircraft with a family of advanced technologies.[115] Recognizing technological advancements are expensive, and analyzing the capabilities of China and Russia, the recommendation is for the United States to continue to modernize and prepare its military to protect its national security interest. Based on the research findings, it is advisable to maintain air superiority; the United States should continue the production of the F-35 Aircraft. In today's world, the very fluid and rapid movement of our adversaries to ramp up development of their Fifth Generation aviation capabilities supports our continued effort to stay the course on the F-35 program which would be in the best interest of our national security.

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